BREEDING BIOLOGY AND RELATION OF POLLUTANTS TO BLACK SKIMMERS AND GULL-BILLED TERNS IN SOUTH CAROLINA

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Breeding Biology and Relation of Pollutants to Black Skimmers and Gull-billed Terns in South Carolina

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Abstract

The breeding biology and relation of pollutants to black skimmers (*Rynchops niger*) and gull-billed terns (*Gelochelidon nilotica*) were investigated in South Carolina from 1969 through 1975. With few exceptions, the two species nested together in colonies located on barrier islands. We located 10 colonies, 7 of which were on the Cape Romain National Wildlife Refuge (Cape Romain); references were located that described nesting on seven other islands in South Carolina that no longer support colonies.

Gull-billed terns nested from early May through July; the skimmers started later (late May) but also continued later (early September). Both species nested in areas subject to tidal flooding, and the two species persisted in nesting in several colonies despite intense predation by rats and gulls. Estimated reproductive success varied greatly from year to year and colony to colony; success in most colonies seemed low, particularly for the gull-billed tern.

Residues of organochlorine pollutants in several eggs seemed of sufficient magnitude to induce adverse effects on reproductivity and eggshell thickness; however, the overall effect of organochlorines appeared negligible.

Maximum numbers of nests located in a single year were 790 for the skimmer and 340 for the gull-billed tern; the total breeding population in South Carolina is unknown. Although nesting islands at Cape Romain and Deveaux Bank are sanctuaries for nesting birds, both species will continue to lose nesting habitat as additional sea islands are developed and inhabited by man.

Black skimmers (*Rynchops niger*) and gull-billed terns (*Gelochelidon nilotica*) frequently nest together in colonies on barrier or spoil islands along the Atlantic and Gulf coasts of the United States. Despite the wide distribution of these two species, their population status and the relation of pollutants to skimmers and gull-billed terns are, with few exceptions, poorly known. Little is known about the biology of these species in South Carolina. The purposes of our study were to investigate the occurrence of organochlorine and heavy metal pollutants in tissues and eggs of skimmers and gull-billed terns, to determine effects of these pollutants on their population status and reproductive success, and to gain some insight into their basic breeding biology in South Carolina.

Methods

We conducted the study on the Cape Romain National Wildlife Refuge (Cape Romain) and surrounding estuarine areas in South Carolina (Fig. 1). Most of the data were gathered from 1971 through 1975 when we were in the field throughout most of the nesting season. Colonies were visited at irregular intervals; visits were usually limited to 1 h or less. We usually censused active nests, recording nest contents and young outside nests, during each visit to the colony.

We marked skimmer nests in one colony in 1971 and in another colony in 1972. We inspected marked nests on each visit to determine the fate of the eggs and young. A sample egg was collected from each nest in a

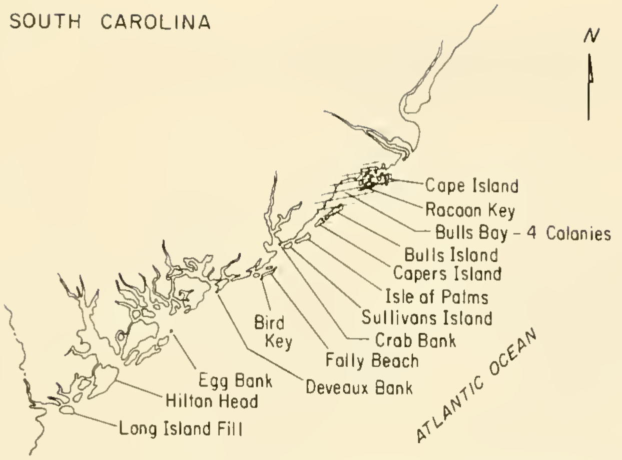


Fig. 1. Location of nesting colonies of black skimmers and gull-billed terns in South Carolina; hatched area represents Cape Romain National Wildlife Refuge.

series of marked and unmarked nests; sample eggs, both viable and addled, were in all stages of incubation. The eggs were weighed, measured, and then opened to determine stage of development and viability. Contents of eggs were placed in chemically cleaned glass bottles that were stored in a freezer. Shell thickness (shell plus shell membranes) was measured at three sites on the waist of the egg with a micrometer graduated in units of 0.01 mm; shell thickness for each egg was represented by an average of the three measurements.

An adult skimmer found dead in South Carolina and four adult skimmers found dead in Florida (Big Pine Key) were frozen for several months before being necropsied. Tissues for histological study were fixed in 10% formalin, embedded in paraffin, sectioned, and stained. Brains and carcasses of the skimmers were later analyzed for residues of organochlorine pollutants, and livers of two birds were analyzed for residues of four heavy metals following methods described by Blus et al. (1977).

Eggs of skimmers and gull-billed terns and tissues of skimmers were analyzed for organochlorine residues. Residue methodology involved electron capture gas chromatography and thin-layer chromatography. A combined gas chromatograph–mass spectrometer was used to confirm residues in about 10% of the samples collected after 1971 (Mulhern et al. 1970; Mulhern et al. 1971; Cromartie et al. 1975). Average recoveries of organochlorines from spiked samples ranged from 75 to 112%; residues were not corrected for recovery values. The level of sensitivity was 0.50 μg/g for the polychlorinated biphenyls (PCB's) and 0.10 μg/g for other organochlorines. Residues in eggs and tissues are presented in μg/g fresh wet weight.

Eggshell thickness and residue data were analyzed statistically by one-way analysis of variance; means for each year were separated by multiple range tests with an adjustment for unequal replication (Kramer 1956). Adequacy of sample size for eggshell thickness and residues was tested by the method of Sokal and Rohlf (1969).

Results

Breeding Biology

Nesting Islands

Skimmers and gull-billed terns in South Carolina nest solely on estuarine islands; they have probably nested on every major sea island in the State. We observed them nesting on nine islands—six of which were at Cape Romain (Figs. 1–3). Because we did not check all of the potential nesting sites in South Carolina, the list is by no means complete.

Gull-billed terns were first recorded breeding in South Carolina in 1929 (Sprunt and Chamberlain 1949). Other islands formerly used for nesting by skimmers are Capers, Sullivans, and Isle of Palms (formerly known as Long Island), but these islands were essentially not used for nesting after 1900 (Wayne 1910). Sullivans Island and Isle of Palms are now largely developed and inhabited by man, and a few people lived on Capers Island (near Bulls Island, Cape Romain) before it was purchased by the State of South Carolina in the 1970's. Capers Island is now managed for wildlife and provides some suitable nesting habitat since excess disturbance from humans and free-ranging livestock has been eliminated.

The two species apparently nested on Hilton Head Island (Caroline Newhall, personal communication), and there is a record of skimmer eggs collected on Bulls Island in 1908 (Fig. 1). We also located skimmer egg collection records from Egg Bank in 1937-38; this island was washed away in the 1940's (Sprunt and Chamberlain 1949). The exact location of several other historical nesting islands was not verified because the name (Lighthouse Bird Bank) is not in current usage or because the nesting site was referred to as "sand island in Bull Bay" or "sand spit 14 miles southwest of Charleston" (U.S. Fish and Wildlife Service 1938-1970; Sprunt 1926). Skimmers have reportedly nested on dredge spoil in only two sites in South Carolina; one was near Folly Beach (Downing 1973) and the other was on Long Island Fill at the mouth of the Savannah River (Tomkins 1933). Most skimmers and gull-billed terns in North Carolina (Soots and Parnell 1975) and skimmers in Texas (Donald White, personal communication) nest on spoil islands, largely because their orig-

Fig. 2. Black skimmer and gull-billed tern colony on Bird Bank; birds in background are in the nesting area. Bird Bank is subject to periodic tidal flooding.

Fig. 3. Black skimmer and gull-billed tern colony on Cape Island Point. Birds in background are in the nesting area. The entire area is also subject to periodic tidal flooding.

inal nesting habitat on the barrier islands is subject to disruptive human activities.

Breeding Population

The maximum number of nests of both species combined was 997 in 1975; this included 790 skimmer nests and 207 gull-billed tern nests. The greatest number of skimmer nests counted in a given year was 790 in 1975; the maximum for gull-billed terns was 340 nests in 1972.

The largest colony on Raccoon Key (Cape Romain) contained 404 pairs in 1973 (Appendix I). Most colonies contained less than 100 pairs. Frequently, the nesting colony had a discontinuous distribution and we arbitrarily divided the colony into several subcolonies. On Raccoon Key, there were 8 subcolonies on 20 June and 14 July 1973; 10 subcolonies (few contained active nests but all contained nest scrapes) were noted on 6 June 1974. The subcolonies on Raccoon Key were scattered along the narrow 6.7-km beach; some were as near as 90 m to one another.

Nesting Associates

Black skimmers and gull-billed terns nested together in every colony we observed except Anderson Creek Shellbank (Cape Romain) where gull-billed terns nested alone. There were a few other colonies where only one of the two species nested in a single year; however, these colonies were small and unsuccessful. About 70% of the breeding population was made up of skimmers (Appendix I). The common tern (*Sterna hirundo*) rarely nests in South Carolina; the two nests that we located were near those of skimmers and gull-billed terns as were four nests of the Caspian tern (*Sterna caspia*). The common tern is a frequent nesting associate of skimmers in Virginia (Erwin 1977) and New York (Gochfeld 1977) and of both skimmers and gull-billed terns in North Carolina (Soots and Parnell 1975; Sears 1978). Skimmers nest with Forster's tern (*Sterna forsteri*) in Louisiana (Chamberlain 1959) and Texas (Donald White, personal communication); and gull-billed terns frequently nest with black-headed gulls (*Larus ridibundus*) in Europe (Møller 1975*b*).

We observed only one instance of black skimmers and gull-billed terns nesting successfully near royal terns (*Sterna maxima*) and Sandwich terns (*Sterna sandvicensis*); that occurred in a small colony on Bird Bank (Cape Romain) in 1975. We have two observations indicating that royal and Sandwich terns exert some dominance over skimmers and gull-billed terns, probably as a result of their superior numbers. On Bird Bank in 1972, skimmers and gull-billed terns deserted a small colony when royal and Sandwich terns moved in to nest. Black skimmer eggs were collected in 1905 on Marsh Island (formerly known as Vessel Reef), and skimmers were observed nesting there around 1910 (Philipp 1910). Neither species nested on Marsh Island (Cape Romain) from 1969 through 1975 when large numbers of royal and Sandwich terns nested there. Royal and Sandwich terns shifted from Marsh Island to Bird Bank where they nested in 1976 and 1977. Skimmers and gull-billed terns did not nest on Marsh Island in 1976. We visited the island twice in 1977; there was no nesting in March but several gull-billed tern nests with eggs were found on 17 May. In 1979, royal and Sandwich terns were still nesting on Bird Bank, and skimmers and gull-billed terns were nesting on Marsh Island (Vivian Mendenhall, personal communication).

Skimmers and gull-billed terns occasionally nested near least terns (*Sterna albifrons*); however, least tern

nests were never found nearer than about 5 m to those of their larger associates. The nesting distribution of the three species was exemplified in the colony located on the southwest point of Cape Island (Cape Romain) on 28 May 1974. We found five distinct subcolonies—three involving least terns and two involving skimmers and gull-billed terns—that were spread out along about 370 m of beach; several subcolonies adjoined one another but did not overlap. Skimmers and gull-billed terns sometimes nested near American oystercatchers (*Haematopus palliatus*) and laughing gulls (*Larus atricilla*), but there was no overlap in nesting areas. The separation of nesting skimmers and gull-billed terns from species occupying similar nesting habitat was also evident in North Carolina colonies (Soots and Parnell 1975). The importance of the laughing gull as an egg predator is discussed in a later section.

Initiation of Breeding and Egg Laying

Some skimmers overwinter in South Carolina, but most migrate south; gull-billed terns are not known to overwinter in the State (Sprunt and Chamberlain 1949). The two nesting associates presented different temporal aspects of reproduction. Gull-billed terns usually laid eggs before skimmers; the earliest record was 4 May compared with 22 May for the skimmer. Bent (1921) collected a skimmer egg on 15 May in South Carolina. Most of the gull-billed tern eggs are laid from late May through early July, whereas most skimmer eggs are laid from late June through early August (Figs. 4A–4G). The skimmer egg-laying season was more prolonged than that of the gull-billed tern; the latest gull-billed tern egg was observed on 28 July compared with 5 September for the skimmer. Skimmers are known for their late initiation of breeding and prolongation of the season into September (Bent 1921; Tomkins 1933). African skimmers (*Rynchops flavirostris*) on Lake Rudolf have a prolonged egg-laying season that begins in March and continues into August (Britton and Brown 1974).

Black skimmers laid their eggs in a scrape they excavated in the sand (Fig. 5), whereas gull-billed terns were more variable and laid in unlined scrapes or they constructed simple to elaborate nests of shell, vegetation, or other materials (Fig. 6). In response to loss of a large number of eggs at one time, such as occurs during abnormally high tides, two peaks of egg laying may occur. Skimmers had two major peaks of laying on Bird Bank in 1972 (Fig. 4A) and one major and one minor peak on Cape Island Point (Cape Romain) in 1975 (Fig. 4F); two peaks of laying by gull-billed terns occurred on Cape Island Point in 1973 (Fig. 4E). On several islands, large numbers of birds occupied a site through much of the nesting season, made numbers of scrapes, but laid few or no eggs (Fig. 4G). This problem will be discussed more fully in the section on egg loss.

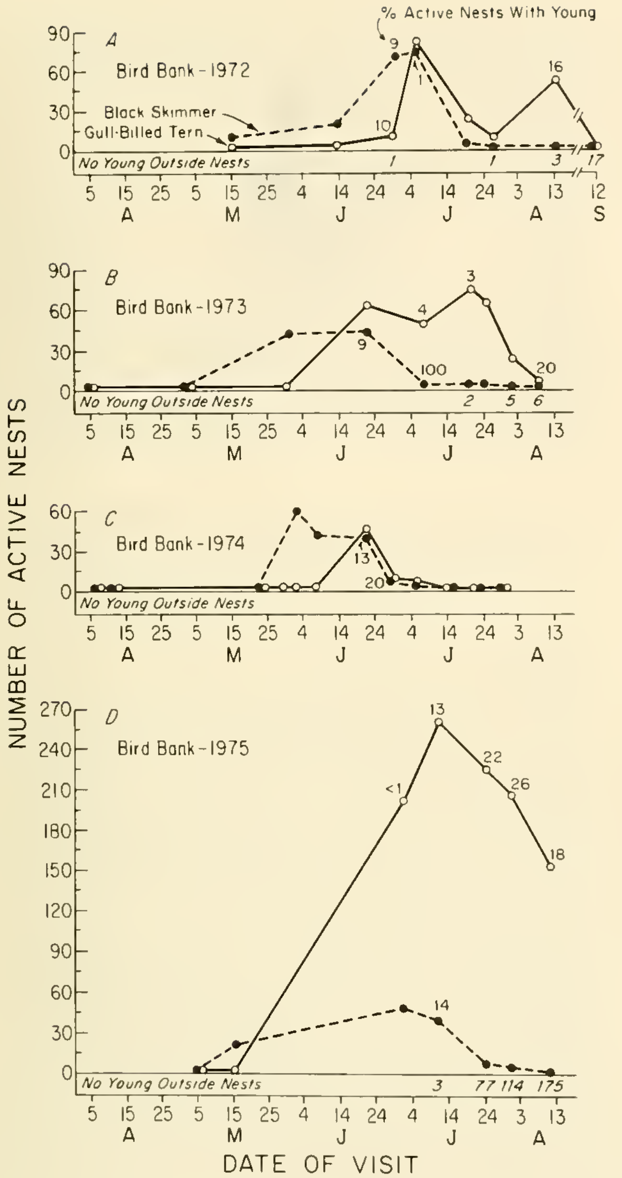
Clutch Size

The average skimmer clutch contained 3.8 eggs in 57 successful nests that were marked on Cape Island Point in 1971; clutch size ranged from two to five eggs. As many as six eggs were seen in several unmarked nests. Clutch size of marked skimmer nests in Virginia averaged 3.6 eggs (Erwin 1977). The average clutch size of 2.3 eggs for the gull-billed tern is imprecise because it is based on single observations of 46 unmarked nests containing both eggs and young; clutch size ranged from 2 to 4. Gull-billed tern clutches in Denmark contained an average of 2.4 eggs (Møller 1975*b*).

Egg Loss

Predation and flooding during rainstorms and high tides were the most important causes of egg loss. During our visits, predation seemed enhanced by the excitable behavior of the birds, especially the black skimmer. Skimmers at nesting colonies frequently flushed several hundred meters ahead when we approached. Except for nonaggressive flights overhead (Fig. 7) and an occasional "broken wing act," skimmers made little active defense of nests containing eggs. Skimmers were observed chasing a laughing gull from the nesting area on one occasion, but the gull succeeded in depredating at least one egg. African skimmers were observed mobbing and chasing predators encroaching on their nesting colony on Lake Rudolf; however, over 15% of the eggs in that colony were lost to predation (Modha and Coe 1969). Nesting gull-billed terns were more aggressive to intruders than black skimmers; they vocalized loudly, and dove toward intruders. However, when we approached the colony, they also usually flushed several hundred meters ahead and remained away from their nests until we moved well away from the colony. Egg predation by laughing gulls ranged from absent to extreme. We observed laughing gull predation on eggs of both species in all colonies; 1.6% of the total eggs observed were depredated by gulls. Laughing gull predation was most extreme on Deveaux Bank, particularly in 1974 when we observed 21 eggs, 16 of which were depredated. From 1972 through 1975, 16% of the 188 eggs observed on Deveaux were depredated; the lowest observed rate of predation was 3% in 1973. The large concentration of laughing gulls (more than 5,000 breeding pairs) coupled with human disturbance seemed the primary factor responsible for nest failure of both species on Deveaux Bank. We did not see a single young skimmer or gull-billed tern during the 4 years, and most eggs were destroyed early in incubation.

A more serious problem in several localities was egg depredation by rats (*Rattus* sp.). In 1971, both species



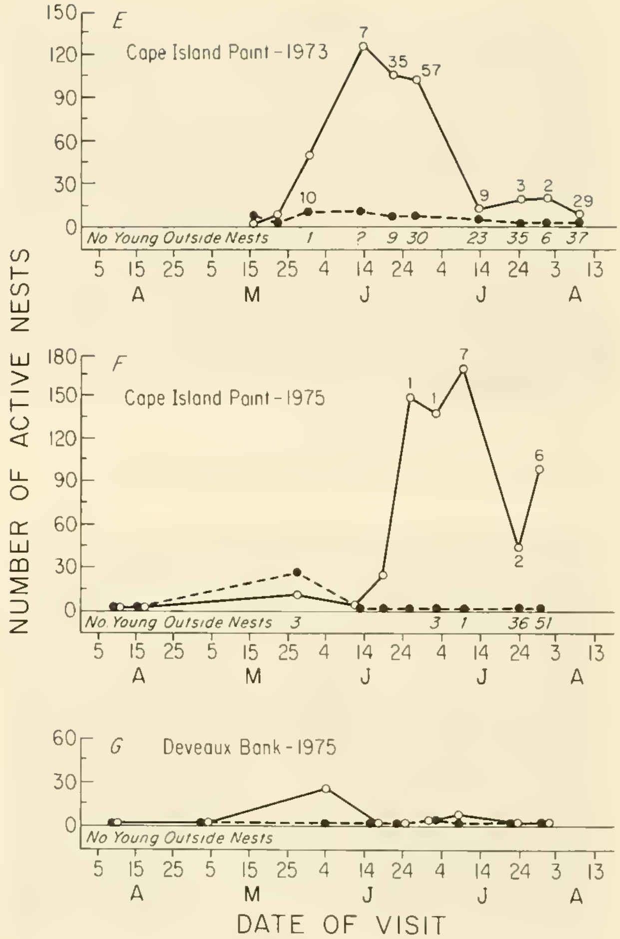


Fig. 4. Temporal aspects of reproductive activity in several colonies of the black skimmer and gull-billed tern in South Carolina. The percentage of active nests with young and number of young of both species outside nests are listed for each observation period; "O" values for these variables are not listed. The "?" on 13 June 1973 (E) indicates young were outside nests but were not counted. In Fig. 4a, for example, there were 10 active skimmer nests on Bird Bank on 29 June 1972 and 1 or 10% had young; there were 73 active gull-billed tern nests and 7 or 9% had young; and there was 1 young outside its nest that was not identified to species.

of the birds nested on Bird Bank on primary dunes that were several meters from cordgrass (*Spartina patens*) that harbored a large population of rats. Rats destroyed every egg in that area, and eggshells of skimmers, gull-billed terns, and American oystercatchers were found piled outside rat burrows. After 1971, the skimmers and terns nested on sand spits on Bird Bank—areas that were about 50 to 200 m from rat habitat (Fig. 2). Nests on the spits were secure from rats but were exposed to tidal flooding.

Predation of eggs by mammals was apparently a minor problem on Raccoon Key during 1971-73, whereas nesting attempts in 1974 and 1975 were seemingly devastated by mammalian predators. Raccoon Key is a long island with a narrow beach that is subject to severe erosion. Subcolonies of both species were all near rat habitat, and raccoons (*Procyon lotor*) were also present. Our work on Raccoon Key was limited so we observed few depredated eggs, and we have little insight into conditions that changed during our period of study. Large numbers of skimmers and gull-billed terns were present on the island for part of

Fig. 5. Clutch of black skimmer eggs laid in a scrape in the sand.

Fig. 6. Nest of gull-billed tern with wrack in and around the nest scrape.

the breeding season in 1974 and 1975; hundreds of nesting scrapes were observed but few eggs were laid.

Both species lost eggs to flooding in every colony because of heavy downpours and high tides. Most nests were on the beaches just above the mean high tide level and females frequently recycled and laid another clutch after their nests were flooded. During the second week of June 1975, all nests on Cape Island Point (Fig. 3) and on the southwest point of Cape Island were washed away by unusually high tides. The birds initiated laying a few days later. At the same time, many nests were lost to flooding on Deveaux Bank, but few nests were flooded on Bird Key (Stono River). Black skimmers are subjected to flooding in all parts of their range; a colony in Virginia was washed away by storm tides (Pettingill 1937). African skimmers also lose large numbers of nests to flooding (Modha and Coe 1969).

Fig. 7. Black skimmer adult in flight over a nesting colony. Note disparity in size of mandibles.

Hatching

Early hatching dates were 31 May for gull-billed terns and 5 June for black skimmers, and late hatching dates were 28 July for the gull-billed terns and 5 September for the skimmers. Most hatching of skimmer and gull-billed tern eggs occurred in June and July (Table 1). The skimmer hatching data are biased because field observations in August were limited and the percentage of young hatching in that month was probably higher than listed in Table 1.

Data from our marked skimmer nests were of limited value because we were unable to visit the colonies frequently enough to obtain accurate measurements of hatching and reproductive success. The young leave the nest scrapes soon after hatching, especially when disturbed, and they frequently take refuge in nest scrapes other than the one in which they hatched (Fig. 8). Our observations indicate that one or more eggs hatched in at least 61% of the 106 marked skimmer nests on Cape Island Point in 1971. The percentage of nests with one or more young varied from 47% where one egg was collected to 63% where no eggs were collected. Only 35% of the 348 eggs were known to hatch, but the fate of a number of eggs was unknown. In 1972, all 10 marked skimmer nests (one egg collected from each) on Bird Bank failed. Skimmers in Virginia hatched 79% of their eggs in nests that were under close surveillance (Erwin 1977).

Survival of Chicks

We found 112 dead young (107 skimmers and 5 gull-billed terns) during our study. Hatchlings are susceptible to intense heat and die within a short time if parents leave them exposed on bare sand during the

Table 1. *Number and percentage of young black skimmers and young gull-billed terns observed in nests in different months, South Carolina, 1971-75.*

Month	Number of young (percent) Black skimmer	Gull-billed tern
May	0 (0)	2 (1)
June	422 (37)	65 (45)
July	552 (48)	77 (54)
August	166 (14)[a]	0 (0)
September	2 (0.2)[a]	0 (0)

[a]Number and percentage for black skimmer are biased low for August and September because we conducted relatively less field work during those months.

Fig. 8. Black skimmer young hiding in sand; young on right hiding in recently constructed scrape and one on the left "freezing" on top of the sand.

heat of the day. In 1971, we located 47 dead young on Cape Island Point; most of the mortality was due to human disturbance, including a film crew. After 1971, we decreased the time and frequency of our visits and thereby caused little or no mortality of young. In contrast to the least tern that nests on developed areas such as Sullivans Island (Blus and Prouty 1979), nesting skimmers and gull-billed terns can tolerate only a small amount of human disturbance.

Heavy rainstorms also caused mortality of chicks. On 14 August 1972, we found 12 dead young on Cape Island Point and 17 on the southwest point of Cape Island. These young were found in or near nests; they apparently died during the heavy rains that occurred several days earlier. We suspect that some newly hatched chicks were probably killed by tidal flooding.

Chick predation was observed on only one occasion. We saw a live gull-billed tern chick upside down in a ghost crab (*Ocypode quadrata*) burrow; the chick had a fresh wound on the tip of a manus after we retrieved it from the burrow. Ghost crabs are known or suspected predators of eggs and young of other species of birds (Sprunt 1948; Beckett 1966). Other potential predators of chicks were rats, raccoons, and gulls. Laughing gulls and herring gulls (*Larus argentatus*) preyed on chicks and eggs of gull-billed terns in North Carolina (Sears 1978). Other causes of mortality of chicks were accidents and diseases; we observed one gull-billed tern chick with a broken wing. The earliest date for fledging was 3 July for both species; several skimmer young fledged as late as September.

Reproductive Success

Success of 91 skimmer nests (no eggs collected) on Cape Island Point in 1971 was high; 111 young hatched and 105 young left the nest. The average number of young leaving each nest was 1.2 per active nest and 1.8 per successful (one or more young hatched) nest. Chicks were noted in 57 of the 91 nests (62.6%); this is a low figure because the fate of 16 nests was unknown. Of 15 marked nests (one egg collected from each) on Cape Island Point in 1971, success was lower than in those nests where eggs were not collected. Adjusting for the egg collected, a minimum of 0.9 young was observed per active nest and 1.6 young per successful nest; young were observed in 46.7% of the nests.

We were only able to estimate reproductive success in most of the colonies that were censused (Appendix I) because of our infrequent visits and our difficulties in obtaining an accurate count of young after they left the nest.

Cumulative counts of young in nests, and the greatest number of young observed outside nests on a single visit, are semiquantitative indices of reproductive success because they are related to both the timing and number of visits to a particular colony. Numbers of young of both species observed outside nests were combined because it was sometimes difficult to positively identify the species of free-ranging chicks. In each colony that was visited three or more times during the breeding season, estimated reproductive success (young fledged per breeding pair) was arbitrarily classified as failed (no young), low (no more than 0.5 young), medium (0.51–1.00 young), or high (more than 1.0 young). Reproductive success tended to be low in most colonies, particularly among gull-billed terns.

There are little other data on the reproductive success of either species. Skimmers in Virginia experienced low reproductive success; young fledged per pair averaged 0.4 in 1973 and 1974 (Erwin 1977). Gull-billed terns in Denmark had high reproductive success and produced 1.5 chicks per pair (Møller 1975*b*), but they apparently experienced low success in North Carolina in 1973 when young were produced in only 17 of 43 nests (Sears 1978).

Adult Mortality

Observed adult mortality during our study in South Carolina included eight skimmers and four gull-billed terns. Seven of the dead adults were found within 6 m of one another in a Raccoon Key subcolony. Summer thunderstorms are common along the South Carolina coast, and the seven birds possibly died from a lightning strike. A female adult skimmer found dead on Cape Island on 10 July 1974 died from aspergillosis. Only one band recovery was recorded during the study; a skimmer banded as a chick on Deveaux Bank on 25 July 1970 was found dead there on 5 July 1973.

Six skimmers involved in a die-off in Florida (Big Pine Key) during February and March 1973 were sent to the Patuxent Wildlife Research Center, Laurel, Maryland. Four of the skimmers were necropsied and exhibited signs of hemorrhagic enteritis, but no pathogenic bacteria were isolated. The enteritis may have been caused by flukes. One of the six skimmers had a broken wing when captured; it later died in captivity.

Eggshell Thickness

Compared with the pre-1947 mean of 0.229 mm, mean thickness of skimmer eggshells ranged from 5.2% lower in 1969 to 4.8% higher in 1971 ($P > 0.05$); gull-billed tern eggshell thickness means ranged from <1.0 to 3.5% lower ($P > 0.05$) than the pre-1947 mean of 0.228 mm (Table 2). We observed 11 skimmer eggs and 2 gull-billed tern eggs that were cracked, crushed, or broken in nests. Most of these eggs were thin-shelled; the eggshell thickness of cracked skimmer eggs ranged from 0.12 to 0.24 mm. Measurement of the shell thickness of a crushed gull-billed tern egg (0.30 mm) was inaccurate because the fragile shell had prominent closely spaced pimples that prevented an accurate measurement of thickness. The number of crushed or cracked eggs seemed to decrease during our study; 11 such eggs were observed from 1971 through 1973 compared with 2 from 1974 through 1975. Gull-billed tern eggs in Denmark exhibited no eggshell thinning (Møller 1975*a*); however, average eggshell thicknesses of skimmers and gull-billed terns in Texas were 4% less than their pre-1943 norms (King et al. 1978).

Residues

Eggs

Residues of 13 organochlorine pollutants were identified in eggs of black skimmers, and residues of 5 pollutants were detected in gull-billed tern eggs (Table 3; Appendix II). Residues of pollutants in skimmer eggs averaged higher than those found in gull-billed tern eggs. During the study, declines in residues of DDE were noted in eggs of both species, and there were declines in dieldrin and PCB's in gull-billed tern eggs (Table 3). However, these trends were not statistically significant ($P > 0.05$) primarily because of the small sample size and the high coefficient of variation (155% for DDE).

Table 2. *Mean eggshell thickness (mm) of eggs of black skimmers and gull-billed terns, South Carolina.* (Standard errors in parentheses.)

	Black skimmer			Gull-billed tern		
Year	n	Mean	SE	n	Mean	SE
Pre-1947	241	0.229[a]	(0.001)	4	0.228	(0.003)
1969	10	0.217	(0.004)			
1971	26	0.238	(0.004)			
1972	11	0.218	(0.004)	10	0.227	(0.004)
1973	21	0.224	(0.004)	7	0.224	(0.005)
1974	12	0.227	(0.005)	17	0.220	(0.002)
1975	23	0.221	(0.003)	5	0.226	(0.002)

[a]There are no significant ($P > 0.05$) differences between means. Means were compared by using a multiple range test (Kramer 1956) and a test for sufficient sample size (Sokal and Rohlf 1969).

A downward trend in DDE residues in gull-billed tern eggs was similar to those noted in eggs of other estuarine birds in South Carolina including the brown pelican (*Pelecanus occidentalis*), least tern, and royal tern (Blus et al. 1977; Blus and Prouty 1979; Blus et al. 1979). There was a slight downward trend for DDE in black skimmer eggs with the exception of an upswing in 1974 (Table 3). No definite trend was evident for PCB residues in skimmer eggs, but there was a downward trend for PCB's in gull-billed tern eggs. Few gull-billed tern eggs contained detectable residues of PCB's in 1974 and 1975. Endrin was not detected in any of the samples. Residues of DDE in South Carolina skimmer eggs were similar to residues in skimmer eggs collected in New York in the late 1960's (Foehrenbach 1972); however, the New York eggs contained DDD and DDT at levels equal to those of DDE. DDT and DDD were rarely found in skimmer eggs in South Carolina.

Tissues

Tissues from the five adult skimmers found dead contained residues of seven organochlorine pollutants (Table 4); residues found most frequently and at the highest levels included DDE and the PCB's. Generally, the brain contained higher residue levels than the carcass. Livers of two skimmers from Florida were analyzed for residues of mercury, copper, zinc, and lead; each of the livers contained residues of the four heavy metals (Table 4). Organochlorines in brains of the five skimmers were well below lethal diagnostic

Table 3. *Geometric means, 95% confidence limits (in parentheses), and ranges (in italics) of residues (μg/g, fresh wet weight) of organochlorine pollutants in eggs of black skimmers (1969, 1971-75) and gull-billed terns (1972-75).*

Species and pollutant[a]	Year and (in parentheses) number analyzed					
	1969 (10)	1971 (21)	1972 (12)	1973 (12)	1974 (8)	1975 (23)
Black skimmer						
DDE	1.94	1.53	1.49	1.10	2.10	0.90
	(1.42–2.65)	(1.07–2.22)	(1.04–2.14)	(0.61–1.98)	(1.38–3.19)	(0.63–1.29)
	0.93–3.88	*0.43–12.12*	*0.78–3.96*	*0.10–3.88*	*1.38–4.69*	*0.21–4.36*
Dieldrin	0.14	0.10			0.11	
	(0.07–0.29)	(0.07–0.14)			(0.06–0.23)	
	ND-0.71	*ND-0.52*	*ND-0.30*	*ND-0.48*	*ND-0.52*	*ND-0.92*
PCB's	1.3	1.6	2.3	2.9	3.9	2.7
	(0.6–3.0)	(0.9–2.9)	(1.0–5.4)	(1.2–6.9)	(2.4–6.5)	(1.9–3.7)
	ND-4.7	*ND-9.0*	*ND-23.8*	*ND-27.7*	*2.3–12.7*	*0.6–17.9*
Mirex	*ND-2.62*	*ND-1.34*	*ND-0.75*	*ND*	*ND-0.82*	*ND-0.61*
OXCH	NA	NA	*ND-0.51*	*ND-0.16*	*ND-0.52*	*ND-0.33*
TNCH	NA	NA	ND	ND	*ND-0.52*	*ND-0.46*
			1972 (11)	1973 (7)	1974 (14)	1975 (5)
Gull-billed tern						
DDE			0.94	0.91	0.39	0.23
			(0.41–2.16)	(0.72–1.15)	(0.29–0.53)	(0.14–0.37)
			0.28–10.71	*0.61–1.32*	*0.18–1.34*	*0.14–0.38*
Dieldrin			*ND-0.59*	*ND-0.11*	*ND-0.39*	*ND*
PCB's			*ND-30.1*	*ND-1.6*	*ND-0.6*	*ND*
Mirex			*ND*	*ND*	*ND*	*ND*
OXCH			*ND-0.29*	*ND*	*ND*	*ND*
TNCH			*ND*	*ND*	*ND*	*ND*

[a]PCB's = polychlorinated biphenyls; OXCH = oxychlordane; TNCH = *trans*-nonachlor; ND = no residue detected; NA = chemical methodology did not identify pollutant.

levels found in brains of experimental birds (Stickel et al. 1966; Stickel et al. 1969, 1970). Levels of organochlorines in whole bodies of skimmers collected on Long Island were relatively low, but similar to the pattern in eggs; residues of DDT and DDD equalled or exceeded those of DDE (Foehrenbach 1972).

Discussion

The black skimmer has adapted to nesting in sites that are susceptible to tidal flooding through its ability to recycle and lay replacement clutches as late as August. Gull-billed terns recycle readily early in the season, but their reproductive season is curtailed much earlier than that of the skimmer. This ability to recycle and lay replacement clutches over a longer period may indicate that skimmers may have some adaptive advantage over the gull-billed terns under conditions that prevail in South Carolina estuaries.

Residues of pollutants probably had little influence on overall reproductive success in the two species, but residues of DDE in several eggs were apparently sufficiently high to induce problems in reproductive success. Eggs of common terns in Alberta, Canada, with dented shells contained an average of nearly 7 μg/g of DDE (Fox 1976); only one of the skimmer eggs and two of the gull-billed tern eggs contained residues exceeding 7 μg/g in the present study. Sampled skimmer eggs—one taken from each of six marked nests that apparently failed—contained from 0.81 to 12 μg/g of DDE. Sample eggs from four marked skimmer nests that were successful contained from 0.43 to 3.40 μg/g of DDE. Two eggs of the gull-billed tern that contained the highest levels of DDE had abnormal shells. The shell thickness of the egg containing 10.71 μg/g of DDE was 0.20 mm, whereas the egg containing 8.75 μg/g of DDE had a fragile pimpled shell.

The interspecific difference in residue content of eggs seemed primarily related to differences in food habits. Pollution patterns in wintering areas may also be a factor, but there are little or no pertinent residue data available on this subject. The gull-billed tern preys on earthworms, spiders, crustaceans, fish, frogs and toads, lizards, small mammals, and the eggs and

Table 4. *Residues (µg/g fresh wet weight) of organochlorine and heavy metal pollutants in tissues of adult black skimmers found dead.*

Locality, date, and sex	Tissue[b]	Pollutant[a] DDE	Dieldrin	OXCH	CCH	Mirex	Toxaphene	PCB's
Big Pine Key, Florida								
Feb-Mar 1973								
Male[c]	C	21.12	0.17	0.56	0.10	ND	0.14	16.9
	B	32.80	0.23	0.88	0.54	ND	ND	32.0
Male	C	3.05	0.10	0.10	0.10	0.13	ND	5.4
	B	3.20	0.15	0.13	0.10	ND	ND	6.8
Female[d]	C	6.89	0.23	0.40	0.15	0.56	ND	13.6
	B	9.40	0.46	0.59	0.26	0.55	ND	20.6
Male	C	2.37	0.28	0.11	0.13	ND	0.16	5.4
	B	2.31	0.23	ND	ND	ND	0.10	3.2
Cape Island, South Carolina								
10 July 1974								
Female	C	0.97	ND	ND	ND	ND	ND	2.5
	B	1.07	ND	ND	ND	ND	ND	3.5

[a]OXCH = oxychlordane; CCH = *cis*-chlordane; PCB's = polychlorinated biphenyls.
[b]Tissue: B = brain; C = carcass.
[c]Residues in liver (µg/g) were mercury, 7.8; copper, 10.5; zinc, 34.0; and lead, <0.1.
[d]Residues in liver (µg/g) were mercury, 8.5; copper, 10.7; zinc, 42.0; and lead, <0.1.

young of other birds (Sprunt and Chamberlain 1949; Rohwer and Woolfenden 1968); black skimmers feed almost exclusively on small estuarine fish (Sprunt and Chamberlain 1949; Erwin 1977). Although the gull-billed tern is considered an estuarine bird, it takes much of its food from terrestrial habitats. Considering residue loads in food of both species in South Carolina, we suspect that residues, particularly PCB's, are lower in the diet of the gull-billed tern.

Although both species frequently change nesting locations and are known for their ability to take advantage of both newly available habitat, as on Marsh Island after 1976 when royal and Sandwich terns left the island to nest on Bird Bank, and newly created nesting habitat such as spoil islands (Erwin 1977; Gochfeld 1977), they are sometimes reluctant to change sites even when conditions change from favorable to unfavorable. On Deveaux Bank during 1964 and 1965, skimmers were reproducing well (Beckett 1966) when only about 400 pairs of laughing gulls nested there. From 1972 through 1975 when the laughing gull breeding population was estimated at over 5,000 pairs, the black skimmers and gull-billed terns apparently failed to raise a single young, yet several hundred birds attempted to nest on the Bank each year under conditions where the huge gull population was responsible for depredation of most eggs as soon as they were laid. A similar situation occurred on Raccoon Key; reproductive success declined from 1972 and 1973 to 1974 and 1975, in apparent response to increased mammalian predator populations. Yet, birds were present on Raccoon Key through the 1974 and 1975 nesting seasons when few eggs were laid in the numerous scrapes that were constructed. Some of the birds eventually moved to other areas to nest, but tenacity to unfavorable nesting sites seemed detrimental and inefficient. Several species of terns, including the common, roseate (*Sterna dougallii*), and arctic (*S. paradisaea*) failed to shift nesting sites on Cape Cod even though a large number of eggs and young were depredated by rats (Austin 1948).

Our census of skimmers and gull-billed terns in South Carolina was incomplete. Total breeding populations in South Carolina are probably similar to populations in North Carolina that are estimated at 1,880 breeding pairs of black skimmers and 520 pairs of gull-billed terns (Soots and Parnell 1975). There are about 15,000 breeding pairs of black skimmers and 90 pairs of gull-billed terns in Louisiana, Alabama, and Mississippi; one colony contained almost 2,500 pairs of skimmers (Portnoy 1978).

Data are insufficient to accurately determine population trends of skimmers in South Carolina. Audubon (1870) quotes Rev. John Bachman as estimating 20,000 black skimmer nests in Bull Bay in South Carolina; we suspect that Bachman either overestimated the number of nests or confused skimmers with royal and Sandwich terns. Recent rough estimates of skim-

mer populations at Cape Romain indicate a maximum of 1,000 nests in 1946 and 1947 (U.S. Fish and Wildlife Service 1938–1970). Beckett (1966) listed 300 pairs of skimmers and 40 pairs of gull-billed terns on Deveaux Bank in 1964 and 200 pairs of skimmers and 15 pairs of gull-billed terns in 1965. Sprunt (1926) counted 231 skimmer nests on a sandbar 23 km southwest of Charleston. With the definite loss of major nesting sites including Sullivans Island, Capers Island, Isle of Palms, Egg Bank, and probable loss of other sites such as Hilton Head, it seems likely that the skimmer population has declined. The gull-billed tern was considered a transient visitor to South Carolina (Wayne 1910) until the initial breeding record in 1929. Since then, there has obviously been a low overall rate of population increase.

Major nesting sites of both species at Deveaux Bank (recently declared an Audubon Society sanctuary and renamed in honor of Alexander Sprunt, Jr.) and Cape Romain are secure from development. Bird Key (Stono River) is owned by the State of South Carolina, but it is not dedicated to nesting birds. Bird Key is one of the most important nesting sites for the two species in South Carolina, and the nesting birds should be given full protection. The future of the two species in South Carolina seems reasonably secure at this time; however, the drastic population declines of the gull-billed tern in most of Europe (Møller 1975*c*), the early extirpation of the skimmer in parts of northeastern United States (Bent 1921), continued loss of nesting habitat to development (Gochfeld 1977), and intolerance of both species to human disturbance indicate that their welfare cannot be taken for granted in any area.

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Appendix I

Estimated reproductive success in colonies of black skimmers (BS) and gull-billed terns (GB), South Carolina.

Year	Colony[a]	Number of visits	Species	Number of nests	Cumulative counts of young in nests	Young outside nests[b]	Estimated young fledged per nest
1971	WB	3			No	nesting	
	RK	1	BS	23[c]	46	43	--[d]
			GB	7[c]	0		--
	CIP	6	BS	197	136	159	0.51-1.00
			GB	30	1		≤ 0.50
	BB	3	BS	189	0	201	> 1.00
			GB	71	3		> 1.00
1972	WB	5	BS	0	0	0	0.00
			GB	1	0		0.00
	AC	3	BS	0	0	0	0.00
			GB	50	0		0.00
	DB	3	BS	2	0	0	0.00
			GB	5	0		0.00
	CIP	7	BS	17	17	13	0.51-1.00
			GB	23	0		≤ 0.50
	CISW	7	BS	67	33	46	0.51-1.00
			GB	27	10		0.51-1.00
	BB	8	BS	81	24	24	> 1.00
			GB	78	7		≤ 0.50
	BK	1	BS	4[c]	0	0	--
			GB	0[c]	0		--
	RK	4	BS	205	46	76	0.51-1.00
			GB	156	34		0.51-1.00
1973	BK	1	BS	195	239	260	--
			GB	27	21		--
	RK	3	BS	245	177	175	> 1.00
			GB	159	38		≤ 0.50
	DB	6	BS	15	0	0	0.00
			GB	3	0		0.00
	CIP	10	BS	117	230	134	> 1.00
			GB	10	3		≤ 0.50
	BB	8	BS	74	7	17	≤ 0.50
			GB	43	10		≤ 0.50

Appendix I (cont.)

Year	Colony[a]	Number of visits	Species	Number of nests	Cumulative counts of young in nests	Young outside nests[b]	Estimated young fledged per nest
	CISW	6	BS	67	49	77	> 1.00
			GB	7	2		≤ 0.50
	AC	4	BS	0	0	0	0.00
			GB	6	0		0.00
	WB	4	BS	0	0	0	0.00
			GB	18	0		0.00
	CB	1	BS	10[c]	2	2	--
			GB	1[c]	0		--
1974	BB	11	BS	45	1	7	≤ 0.50
			GB	60	10		≤ 0.50
	WB	2			No nesting		
	DB	6	BS	3	0	0	0.00
			GB	0	0		0.00
	BK	2	BS	18	0	20	--
			GB	50	1		--
	CIP	8	BS	94	12	14	≤ 0.50
			GB	34	7		≤ 0.50
	RK	4	BS	10	0	0	0.00
			GB	3	0		0.00
	CISW	6	BS	11	0	NR[e]	≤ 0.50
			GB	15	1		≤ 0.50
1975	BK	4	BS	238	95	163	> 1.00
			GB	57	13		≤ 0.50
	AC	2			No nesting		
	CIP	10	BS	173	> 29[f]	61	≤ 0.50
			GB	28	0		≤ 0.50
	BB	9	BS	262	261	215	> 1.00
			GB	52	13		0.51-1.00
	WB	10	BS	53	29	28	0.51-1.00
			GB	46	10		≤ 0.50
	CISW	8	BS	16	0	0	0.00
			GB	1	0		0.00
	DB	9	BS	26	0	0	0.00
			GB	2	0		0.00
	RK	7	BS	22	0	0	0.00
			GB	21	0		0.00

Appendix I (concluded)

Notes.

[a] WB = White Banks, RK = Raccoon Key, CIP = Cape Island Point, BB = Bird Bank, AC = Anderson Creek Shellbank, DB = Deveaux Bank, CISW = Cape Island, southwest point, BK = Bird Key, CB = Crab Bank.

[b] Young of both species combined; greatest number of young observed outside nests during one visit (see text).

[c] The number of nests is too low because counts were taken either before peak of laying or after most young had left their nests.

[d] -- = insufficient data for estimate.

[e] NR = several young fledged but exact number not recorded.

[f] Count incomplete; total probably near 40.

Appendix II

Residues of organochlorine pollutants in eggs of black skimmers and gull-billed terns, South Carolina.

Year	Residues (µg/g, fresh wet weight)[a]					
	DDE	Dieldrin	PCB's	Mirex	OXCH	TNCH
BLACK SKIMMER						
1969	1.90[b]	--	--	--		
	2.12	--	--	--		
	0.90	--	--	--		
	3.88	0.29	3.9	--		
	3.65	0.71	4.7	--		
	2.40	0.25	2.0	2.62		
	1.77	0.16	1.8	0.72		
	1.56	0.47	1.9	--		
	1.35	0.12	1.8	--		
	1.63	--	3.7	--		
1971	0.81	--	--	--		
	4.23	0.52	9.0	0.26		
	0.43	--	--	0.26		
	1.15	--	1.8	--		
	3.58	0.50	9.0	0.29		
	2.12	0.15	1.9	1.34		
	1.09	--	--	--		
	1.25	--	2.0	--		
	3.40	0.17	2.9	--		
	12.12	0.17	2.9	0.27		
	1.42	--	3.8	0.24		
	1.08	0.19	2.0	0.32		
	4.71	0.29	7.4	0.26		
	0.86	--	1.4	--		
	0.63	--	--	--		
	1.37[c]	--	5.3	--		
	0.87	0.14	3.2	--		
	0.81	--	--	--		
	1.09	0.13	1.8	0.22		
	2.60	0.13	6.5	--		
	1.19	--	--	--		
1972	3.47[d]	0.14	4.9	0.75	0.51	--
	0.90	--	--	--	--	--
	1.16	--	--	--	--	--
	2.39	--	13.9	0.27	--	--
	0.78	--	2.1	0.31	--	--
	0.88	--	2.2	0.37	--	--
	2.59	--	2.2	--	--	--
	0.82	--	1.8	--	--	--
	1.37	--	4.2	--	--	--
	1.27	--	1.6	0.20	--	--
	3.96	0.17	23.8	0.10	--	--
	1.38	0.30	1.6	--	--	--
1973	0.10	--	--	--	--	--
	0.84	--	2.5	--	--	--
	2.12[e]	0.48	5.2	--	--	--
	1.32	0.14	27.7	--	--	--
	3.88	--	9.4	--	--	--
	0.81	--	0.7	--	--	--

Appendix II (cont.)

Year	Residues (µg/g, fresh wet weight)[a]					
	DDE	Dieldrin	PCB's	Mirex	OXCH	TNCH
	2.00	--	2.2	--	--	--
	0.50	--	0.4	--	--	--
	1.13	0.12	2.3	--	--	--
	1.67	0.12	9.2	--	--	--
	1.49	--	6.8	--	0.16	--
	1.56[f]	0.12	4.0	--	--	--
1974	4.69	0.16	12.7	0.82	0.16	0.18
	1.34	--	3.2	--	--	--
	4.41	0.19	3.3	--	--	0.10
	1.98[g]	0.52	8.0	0.28	0.52	0.52
	1.89	--	2.6	--	--	--
	1.41	--	3.2	--	--	0.11
	1.85	0.14	2.3	--	--	--
	1.38[h]	0.10	2.7	--	--	--
1975	1.18[i]	--	1.4	--	--	0.10
	2.70	0.32	2.1	--	--	--
	0.42	--	1.7	--	--	--
	0.91	0.16	17.9	--	0.23	0.17
	1.27	0.11	3.9	--	--	0.10
	1.41[j]	--	4.4	--	0.25	0.46
	0.94	0.11	2.3	--	--	0.11
	1.18	0.10	2.6	--	--	0.10
	0.50	--	2.2	--	--	--
	1.23	0.16	4.4	--	--	0.17
	0.67	--	1.6	--	--	--
	5.71	0.92	5.9	0.61	0.33	0.29
	2.54[k]	0.21	8.8	--	0.22	0.18
	4.36	0.46	1.7	--	--	--
	0.21	--	0.6	--	--	--
	0.44	--	1.2	--	--	--
	0.71	--	4.6	--	0.11	0.11
	0.80	--	6.2	--	--	0.12
	0.30	--	1.1	--	--	--
	0.61	0.19	2.4	--	--	0.12
	0.35	--	1.3	--	--	--
	0.43	--	2.3	--	--	--
	1.01	--	2.8	--	--	--
GULL-BILLED TERN						
1972	0.60	0.31	--	--	--	--
	10.71	0.21	--	--	--	--
	0.50	--	--	--	--	--
	0.36	--	--	--	--	--
	0.94	--	--	--	--	--
	0.30	0.59	--	--	--	--
	0.56	--	--	--	--	--
	1.05	--	2.6	--	--	--
	1.02	--	--	--	--	--
	0.28[l]	--	--	--	--	--
1973	0.94	0.11	--	--	--	--
	1.01	--	0.5	--	--	--
	1.08	--	0.9	--	--	--
	0.61	--	--	--	--	--
	0.78	--	--	--	--	--
	0.82	0.10	--	--	--	--

Appendix II (concluded)

Year	Residues (μg/g, fresh wet weight)[a]					
	DDE	Dieldrin	PCB's	Mirex	OXCH	TNCH
	1.32	--	1.6	--	--	--
1974	0.39	--	--	--	--	--
	1.34	--	--	--	--	--
	0.32	--	--	--	--	--
	0.23	--	0.5	--	--	--
	0.18	--	--	--	--	--
	0.93	0.39	--	--	--	--
	0.37	0.22	--	--	--	--
	0.31	0.11	--	--	--	--
	0.25	--	--	--	--	--
	0.41	--	0.5	--	--	--
	0.34	--	0.6	--	--	--
	0.43	--	--	--	--	--
	0.40	--	--	--	--	--
	0.45	0.22	--	--	--	--
1975	0.38	--	--	--	--	--
	0.22	--	--	--	--	--
	0.28	--	--	--	--	--
	0.14	--	--	--	--	--
	0.19	--	--	--	--	--

Notes.

[a] PCB's = polychlorinated biphenyls, OXCH = oxychlordane, TNCH = _trans_-nonachlor, ND or -- = no residue detected, blank space = chemical methodology did not identify pollutant.
[b] Also contained 0.10 μg/g DDT.
[c] Also contained 0.30 μg/g heptachlor epoxide.
[d] Also contained 0.19 μg/g _cis_-nonachlor.
[e] Also contained 0.14 μg/g of _cis_-chlordane and 0.30 μg/g of hexachlorobenzene.
[f] Also contained 0.10 μg/g of _cis_-chlordane.
[g] Also contained 0.24 μg/g DDD, 0.12 μg/g heptachlor epoxide, 0.20 μg/g _cis_-chlordane, and 0.15 μg/g _cis_-nonachlor.
[h] Also contained 0.10 μg/g of toxaphene.
[i] Also contained 0.16 μg/g of toxaphene.
[j] Also contained 0.13 μg/g of DDD.
[k] Also contained 0.11 μg/g of toxaphene.
[l] Each egg contained 0.11 μg/g of _cis_-nonachlor.

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